Eur päisches Patentamt	European Patent Office	Office européen des brevets

x

THIS PAGE BLANK (USPTO)

Europäisches
Patentamt

Eur pean
Patent Office

Office européen
des brevets

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.:   00306237.9
Demande n°:

Anmeldetag:
Date of filing: 21/07/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
ASM LITHOGRAPHY B.V.

5503 LA Veldhoven

NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
   Assist features for use in lithographic projection

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:

/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

THIS PAGE BLANK (USPTO)

P-0198.000-EP   - 1 -

Assist Features for use in Lithographic Projection

The present invention relates to masks, having assist features, for use in methods

5   of manufacturing devices using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate;

and

10   a projection system for imaging an irradiated portion of the mask onto a target

portion of the substrate; a typical method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table;

and

15   imaging said irradiated portions of the mask onto said target portions of the

substrate.

For the sake of simplicity, the projection system may hereinafter be referred to as

20   the "lens"; however, this term should be broadly interpreted as encompassing various types

of projection system, including refractive optics, reflective optics, catadioptric systems, and

charged particle optics, for example. The illumination system may also include elements

operating according to any of these principles for directing, shaping or controlling the

projection beam, and such elements may also be referred to below, collectively or

25   singularly, as a "lens". In addition, the first and second object tables may be referred to as

the "mask table" and the "substrate table", respectively.

In the present document, the terms "radiation" and "beam" are used to encompass

all types of electromagnetic radiation or particle flux, including, but not limited to,

ultraviolet radiation (e.g. at a wavelength of 365nm, 248nm, 193nm, 157nm or 126nm),

30   extreme ultraviolet radiation (EUV), X-rays, electrons and ions. Also herein, the invention

is described using a reference system of orthogonal X, Y and Z directions, and rotation

about an axis parallel to the I direction is denoted Ri. Further, unless the context

otherwise requires, the term "vertical" (Z) used herein is intended to refer to the direction normal to the substrate or mask surface or parallel to the optical axis of an optical system, rather than implying any particular orientation of the apparatus. Similarly, the term "horizontal" refers to a direction parallel to the substrate or mask surface or perpendicular

5   to the optical axis, and thus normal to the "vertical" direction.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion or exposure area (comprising one or more dies) on a substrate (silicon wafer) which

10   has been coated with a layer of radiation sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions which are successively irradiated via the reticle, one at a time. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus —

15   which is commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is

20   scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO97/33205, for example.

In general, lithographic apparatus contain a single mask table and a single substrate table. However, machines are becoming available in which there are at least two

25   independently moveable substrate tables; see, for example, the multi-stage apparatus described in International Patent Applications WO98/28665 and WO98/40791. The basic operating principle behind such multi-stage apparatus is that, while a first substrate table is at the exposure position underneath the projection system for exposure of a first substrate located on that table, a second substrate table can run to a loading position, discharge a

30   previously exposed substrate, pick up a new substrate, perform some initial metrology steps on the new substrate and then stand ready to transfer the new substrate to the exposure position underneath the projection system as soon as exposure of the first

substrate is completed; the cycle then repeats. In this manner it is possible to increase substantially the machine throughput, which in turn improves the cost of ownership of the machine. It should be understood that the same principle could be used with just one substrate table which is moved between exposure and loading positions.

5   It is known to provide so-called "assist features" in masks to improve the image projected onto the resist and ultimately the developed device. Assist features are features that are not intended to appear in the pattern developed in the resist but are provided in the mask to take advantage of diffraction effects so that the developed image more closely resembles the desired circuit pattern. Assist features are generally "sub-resolution"

10   meaning that they are smaller in at least one dimension than the smallest feature in the mask that will actually be resolved on the wafer. Assist features may have dimensions defined as fractions of the "critical dimension", which is the smallest width of a feature or smallest separation between features in the mask and is often the resolution limit of the lithographic projection apparatus with which the mask is to be used. Note though that

15   because the mask pattern is generally projected with a magnification of less than 1, e.g. 1/4 or 1/5, the assist feature on the mask may have a physical dimension larger than the smallest feature on the wafer. Two types of assist features are known. Scattering bars are lines with a sub-resolution width placed on one or both sides of an isolated conductor to mimic proximity effects that occur in densely packed regions of a pattern. Serifs are

20   additional areas of various shapes placed at the corners and ends of conductor lines, or the corners of rectangular features, to make the end of the line, or the corner, more nearly square or round, as desired. Further information on the use of scattering bars and serifs can be found in US 5,242,770 and US 5,707,765, for example.

         Contact holes, or vias, in integrated circuits cause particular problems in imaging.

25   Because the contact holes often have to be formed through numerous or relatively thick process layers previously formed on the wafer, they must be patterned into a relatively thick layer of photoresist, requiring an increased depth of focus in the aerial image of the mask pattern.

30

P-0198.000-EP   - 4 -

An object of the present invention is to provide an improved mask for better imaging of irregularly-spaced dense features, such as contact holes, as well as a method of making such a mask and a method of manufacturing devices using the improved mask.

According to the present invention there is provided a mask for use in a
5   lithographic projection apparatus, the mask comprising a plurality of isolated areas that contrast with the background and represent features to be printed in manufacture of a device, said isolated areas arranged generally in an array; characterized by:

a plurality of assist features smaller than said isolated areas and positioned so as to make said array more nearly symmetric.

10   The assist features, by reducing asymmetry in the array, tend to reduce aberrations in the aerial image and are ideally located so as to reduce all asymmetric aberrations, caused by odd aberrations such as 3 wave and coma. In an array that already has some degree(s) of symmetry, the assist features may add additional degrees of symmetry or may make a unit (primitive) cell more symmetric. In this way, the invention can provide improvements in
15   imaging symmetry that are largely independent of exposure device and illumination or projection settings. In many cases, the isolated features can be seen as occupying lattice points of a regular array (though the isolated features may be displaced slightly from the points of an ideal lattice) but with one or more of the points of the unit, or primitive, cell being vacant. In this case, the assist features are placed at at least some of the vacant lattice
20   points.

The assist features should be sufficiently small in at least one dimension so as not to appear in the developed pattern of the resist, though they may be detectable in the aerial image and may partially expose the photo- (energy sensitive) resist. The assist features are therefore generally smaller than the critical dimension of the mask pattern and the
25   resolution limit of the lithographic apparatus with which the mask is to be used.

The isolated areas may for example represent contact holes to be formed in a DRAM array. The isolated areas and assist features may be transparent areas on a relatively opaque background or vice versa. In a reflective mask, the isolated areas and assist features will have a different reflectivity than the background. In a phase shift mask,
30   the isolated areas and assist features may introduce a different phase shift and/or a different attenuation than the background. The assist features need not have the same "tone" as the isolated areas.

P-0198.000-EP   - 5 -

According to another aspect of the invention there is provided a method of making a mask for use in a lithographic projection apparatus, the method comprising the step of defining a plurality of isolated areas that contrast with the background and represent features to be printed in manufacture of a device, said isolated areas arranged

5   generally in an array; characterized by the further step of:

defining a plurality of assist features smaller than said isolated areas and positioned so as to make said array more nearly symmetric.

The positions, shapes and sizes of the assist features may be determined by calculating aberrations in the wavefront that would be produced by the pattern without

10   them and then determining positions, etc., for the assist features that reduce the predicted aberrations, especially 3 wave and 1 wave (comatic) aberrations.

According to a further aspect of the present invention there is provided a method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

15   a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate; the method comprising the steps of:

20   providing a mask bearing a pattern to said first object table, said mask comprising a plurality of isolated areas that contrast with the background and represent features to be printed in manufacture of a device, said isolated areas arranged generally in an array;

providing a substrate having a radiation-sensitive layer to said second object table; and

25   imaging said irradiated portions of the mask onto said target portions of the substrate; characterized in that:

said mask further comprises a plurality of assist features smaller than said isolated areas and positioned so as to make said array more nearly symmetric.

In a manufacturing process using a lithographic projection apparatus according to

30   the invention a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake.

P-0198.000-EP   - 6 -

After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching,

5   ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices (dies) will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual

10   devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

        Although specific reference may be made in this text to the use of the apparatus

15   according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any

20   use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "exposure area", respectively.

25   The present invention will be described below with reference to exemplary embodiments and the accompanying schematic drawings, in which:

        Figure 1 depicts a lithographic projection apparatus with which embodiments of the invention can be used;

        Figure 2 depicts a part of a mask pattern for printing contact holes in the

30   manufacture of a dynamic random access memory (DRAM);

        Figure 3 depicts a part of a mask pattern according to a first embodiment of the present invention for printing contact holes in a DRAM;

P-0198.000-EP   - 7 -

Figure 4 is a graph of intensities of part of the aerial images produced by the mask patterns of Figures 2 and 3;

Figure 5 depicts a part of an alternative mask pattern for printing contact holes;

Figure 6 depicts a part of a mask pattern according to a second embodiment of the

5   invention;

Figure 7 is a graph of intensities of part of the aerial images produced by the mask patterns of Figures 5 and 6;

Figure 8 depicts part of a mask pattern for printing rectangular features;

Figure 9 depicts part of a mask pattern according to a third embodiment of the

10   invention for printing rectangular features;

Figure 10 is a contour plot of intensities of a part of the aerial images produced by the mask patterns of Figures 8 and 9; and

Figure 11 is a table of Zernike polynomials.

In the drawings, like references indicate like parts.

15

Lithographic Projection Apparatus

Figure 1 schematically depicts a lithographic projection apparatus which may be used with the invention. The apparatus comprises:

20   •   a radiation system comprising radiation source LA and illumination system IL for supplying a projection beam PB of radiation (e.g. UV or EUV radiation or an electron or ion beam);

•   a first object table (mask table) MT provided with a mask holder for holding a mask MA (e.g. a reticle), and connected to first positioning means for accurately

25   positioning the mask with respect to item PL;

•   a second object table (substrate or wafer table) WT provided with a substrate holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;

•   a projection system ("lens") PL (e.g. a refractive or catadioptric system, a mirror

30   group or an array of field deflectors) for imaging an irradiated portion of the mask MA onto an exposure area C (target portion) of a substrate W held in the substrate table WT.

P-0198.000-EP   - 8 -

As here depicted, the apparatus is of a transmissive type (i.e. has a transmissive mask). However, in general, it may also be of a reflective type, for example.

The radiation system comprises a radiation source LA (e.g. a Hg lamp, excimer laser, an undulator provided around the path of an electron beam in a storage ring or
5   synchrotron, a laser-induced plasma source or an electron or ion beam source) which produces a beam of radiation. This beam is caused to traverse various optical components comprised in the illumination system IL — e.g. beam shaping optics Ex, an integrator IN and a condenser CO — so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

10   The beam PB subsequently intercepts the mask MA which is held in a mask holder on a mask table MT. Having passed through the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto an exposure area C of the substrate W. With the aid of the interferometric displacement measuring means IF, the substrate table WT can be moved accurately by the second positioning means, e.g. so as to position
15   different exposure areas C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning),
20   which are not explicitly depicted in Figure 1. In the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table may be connected only to a short-stroke positioning device, to make fine adjustments in mask orientation and position; or the mask table may be fixed.

The depicted apparatus can be used in two different modes:
25   1.   In step-and-repeat (step) mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto an exposure area C. The substrate table WT is then shifted in the X and/or Y directions so that a different exposure area C can be irradiated by the beam PB;

2.   In step-and-scan (scan) mode, essentially the same scenario applies, except that a
30   given exposure area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently,

the substrate table WT is moved in the same or opposite direction at a speed V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large exposure area C can be exposed, without having to compromise on resolution.

5   Figure 2 shows part of a conventional 6% attenuated phase shift mask pattern which may be used in the lithographic projection apparatus described above for forming contact holes (vias) in a dynamic random access memory (DRAM) device. The mask pattern has an array of transparent areas 110, which let through the exposure radiation to expose the resist in the areas where contact holes are to be formed, in a substantially 10   opaque field. It will be seen that the transparent areas are arranged such that a group of three, referenced 111, 112, 113, repeats regularly. The contact holes are 0.2µm square with the spacing between contacts 0.1µm. A refernce area 120 of 0.3 x 1.2µm² is also shown. The transparent areas 110 may be displaced from the points of a rectangular array and differ in size to compensate for predicted proximity effects.

15   The inventors have discovered that these contact holes do not image correctly, being misshapen and displaced from their nominal positions.

Embodiment 1

       According to the present invention, assist features are added to the mask pattern to 20   make the array of features more nearly symmetric. Suitable positions and dimensions for the assist features are determined empirically by consideration of the Zernike coefficients representing wavefront aberrations in the image that will be produced from the pattern and postulated assist features.

       The wavefront aberrations can be written as a series according to their angular 25   form:

$$W(r,\theta) = \sum_m R_m(r)\cos(m\theta) + R'_m(r)\sin(m\theta)$$

where r and θ are radial and angular co-ordinates, respectively, (r is normalized) and m is an index indicating the contribution of the mth aberration. R and R' are functions of r.

30   The aberration can also be expressed in terms of the Zernike expansion:

$$W = Zif_i(r,\theta) + Zjf_j(r,\theta) + Zkf_k(r,\theta) + \ldots$$

P-0198.000-EP   - 10 -

where each Z is the Zernike coefficient and each f is the corresponding Zernike polynomial. The functions f take the form of the product of a polynomial in r and sin or cos of $m\theta$. For example, the comatic aberration ($m=1$) can be represented by a Zernike series in Z7, Z8, Z14, Z15, Z23, Z24, Z34, Z35 etc., and, for example, the function

5   associated with the Z7 coefficient [$f_7(r,\theta)$ in the notation above] is:

$$(3r^3 - 2r)\cos(\theta)$$

The Zernike expansion for the lower-order aberrations is summarized in the table given in Figure 11.

In particular, the inventors have determined that substantial improvements can be

10   achieved by arranging assist features to manipulate the odd aberrations (odd m-numbers), especially the Z10 (3 wave) coefficient. Improvements can also be obtained by arranging assist features to reduce coma (1 wave) aberrations in the aerial image. The positions, shapes and sizes of assist features can be determined using known computational techniques, such as the program known as "Solid C", a commercial software package

15   supplied by the company Sigma-C GmbH in Germany, for simulating and modeling optical lithography. Other suitable software packages, such as one known as "Prolith", may alternatively be used.

In the DRAM example, improvements are achieved by regarding the six repeated transparent areas as two pairs of triplets A, B, C and D, E, F with each member of the

20   triplet occupying one of the four corners of a square (in this example) unit cell. According to the invention, assist features 151, 152 are placed at the fourth corners and comprise a transparent square of a size too small to be printed in the developed pattern. The squares can be 0.12μm each side, for example. Note that the assist features may be visible in the aerial image and partly expose the resist but be washed out in development of the resist.

25   The efficacy of the present invention is seen in Figure 4 which is a graph of intensity in the aerial images produced by the mask patterns of Figures 2 and 3 corresponding to the line 130. In Figure 4 the solid line represents the intensity of the aerial images produced by the mask pattern according to the invention (Figure 3) and the dashed line represents the intensity of the aerial image produced by the conventional mask

30   pattern (Figure 2). The asymmetry of printing can be represented by the distances L and R shown in Figure 4; these represent the distances between the peaks which will form the contact holes, measured at the resist threshold, chosen as 0.25 in the arbitrary units of the

P-0198.000-EP   - 11 -

graph of Figure 4. It can be seen that the distance L is reduced with the invention so that the asymmetry represented by the difference L – R is also reduced.

Embodiment 2

5   Figure 5 shows an alternative arrangement of contact holes 110. In this arrangement a pair of contact holes 211, 212 repeats to form a honeycomb structure. The contact holes may be 0.2μm square with a spacing between adjacent contacts of 0.1μm. Also shown is a refernce area 220 of 0.3 x 0.9μm². According to the invention, the symmetry of this mask pattern is improved, as shown in Figure 6, by adding an additional

10   assist feature 251 at the centre of each honeycomb cell. The assist features 251 may be square of size 0.12μm, for example.

          The improvement provided by the present invention in the second embodiment can be seen in Figure 7 which is a graph of intensities of the aerial images produced by the mask patterns of Figures 5 and 6 along the line 230. As with Figure 4, the solid line

15   represents the intensity of the image produced by the mask pattern according to the invention (Figure 6) and the dashed line that of the conventional pattern (Figure 5). It will clearly be seen that the aerial image produced by the pattern according to the invention is less asymmetric.

20   Embodiment 3

          Figure 8 shows a conventional "brick wall" pattern of rectangles arranged in a staggered line.. The rectangles are 0.2 x 0.5μm² with a spacing between adjacent rectangles of 0.1μm. The refernce area 320 is 0.6 x 0.6μm². As shown in Figure 9, according to the invention, assist features 350 are placed between the rectangles 310. The assist features may

25   again be 0.12μm on each side, for example.

          Figure 10 is a contour plot at a 0.25 (arbitrary units) intensity threshold of the aerial image produced by the unit cell 320. The finely-dashed line represents the image produced by the present invention (Figure 9) whilst the single-chain line represents that produced by the conventional mask pattern (Figure 8). The double-chain line represents an

30   ideal aerial image of the mask pattern with no 3 wave aberration. It will clearly be seen that the image provided by the present invention is closer to the ideal.

　　　　Whilst we have described above specific embodiments of the invention it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention. It should be explicitly noted that the
5　present invention can be applied to any mask pattern having an (asymmetric) array or group of features. It should also be noted that the invention is applicable where the array comprises only part of the mask pattern, for example in the manufacture of system-on-chip devices combining memory and logic or processors on a single device.

P-0198.000-EP   - 13 -

CLAIMS

1.   A mask for use in a lithographic projection apparatus, the mask comprising a
plurality of isolated areas that contrast with the background and represent features to be
printed in manufacture of a device, said isolated areas arranged generally in an array;
characterized by:

a plurality of assist features smaller than said isolated areas and positioned so as to
make said array more nearly symmetric.

2.   A mask according to claim 1 wherein said isolated areas are arrayed in groups
defining a unit cell and said assist features are positioned so as to make said unit cell more
nearly symmetric.

3.   A mask according to claim 2 wherein said isolated areas are positioned at or near
some of the points of one or more regular unit cells and said assist features are positioned at
points of the regular unit cell(s) not occupied by said isolated areas.

4.   A mask according to claim 3 wherein said isolated areas are positioned at three of
the corners of a rectangular unit cell and said assist features are positioned at the fourth
corner.

5.   A mask according to claim 1, 2, 3 or 4 wherein said assist features are positioned so
as to reduce the effect of at least one odd aberration in the wavefront produced by said
mask pattern when illuminated by exposure radiation in said lithographic projection
apparatus.

6.   A mask according to any one of claims 1 to 5 wherein said assist features are
positioned so as to reduce the effect of 3 wave and/or comatic (1 wave) aberration in the
wavefront produced by said mask pattern when illuminated by exposure radiation in said
lithographic projection apparatus.

P-0198.000-EP   - 14 -

7.   A mask according to any one of claims 1 to 6 wherein said assist features have the same contrast to the background of said mask as said isolated areas.

8.   A mask according to any one of the preceding claims wherein said isolated features
5   are more transparent to the exposure radiation of said lithographic projection apparatus than said background.

9.   A mask according to any one of claims 1 to 7 wherein said isolated features are more reflective of the exposure radiation of said lithographic projection apparatus than said
10   background.

10.   A mask according to any one of claims 1 to 7 wherein said isolated features impart a different phase shift than said background.

15   11.   A mask according to any one of the preceding claims wherein said assist features are smaller than a critical dimension of said mask.

12.   A mask according to claim 11 wherein said assist features are smaller than a resolution limit of said lithographic projection apparatus.
20

13.   A method of making a mask for use in a lithographic projection apparatus, the method comprising the step of defining a plurality of isolated areas that contrast with the background and represent features to be printed in manufacture of a device, said isolated areas arranged generally in an array; characterized by the further step of:
25   defining a plurality of assist features smaller than said isolated areas and positioned so as to make said array more nearly symmetric.

14.   A method according to claim 12 comprising the further steps of:
             determining wavefront aberrations in an aerial image that would be produced in
30   said lithographic apparatus by the pattern of said isolated areas; and
             determining positions, shapes and sizes for said plurality of assist features so as to reduce aberrations in said aerial image.

P-0198.000-EP   - 15 -

15.   A method according to claim 14 wherein said positions for said plurality of assist features are determined so as to reduce 3 wave and/or 1 wave (comatic) aberrations.

5   16.   A method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate;

10   and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table, said mask comprising a plurality of isolated areas that contrast with the background and represent features to be

15   printed in manufacture of a device, said isolated areas arranged generally in an array;

providing a substrate having a radiation-sensitive layer to said second object table; and

imaging said irradiated portions of the mask onto said target portions of the substrate; characterized in that:

20   said mask further comprises a plurality of assist features smaller than said isolated areas and positioned so as to make said array more nearly symmetric.

17.   A method according to claim 16 wherein said device includes a memory array, especially a dynamic random access memory array.

25

18.   A device manufactured according to the method of claim 16 or 17.

19.   A method according to claim 16 wherein said assist features have a largest dimension less than about 50% of the wavelength of said projection beam, preferably in the

30   range of from 30 to 40% of the wavelength of said projection beam.

THIS PAGE BLANK (USPTO)

P-0198.000-EP   - 16 -

ABSTRACT

Assist Features for use in Lithographic Projection

5

    In a mask pattern for a device such as a DRAM including a nearly regular array of isolated features, assist features are positioned so as to make the array more nearly symmetric. Where the isolated features are positioned at most but not all of the points of a regular unit cell, the assist features may be positioned at the points of the unit cell not occupied by the isolated features. The isolated features may represent contact holes.

10

Fig. 7

Fig. 1

Fig. 2

3 / 8

Fig. 3
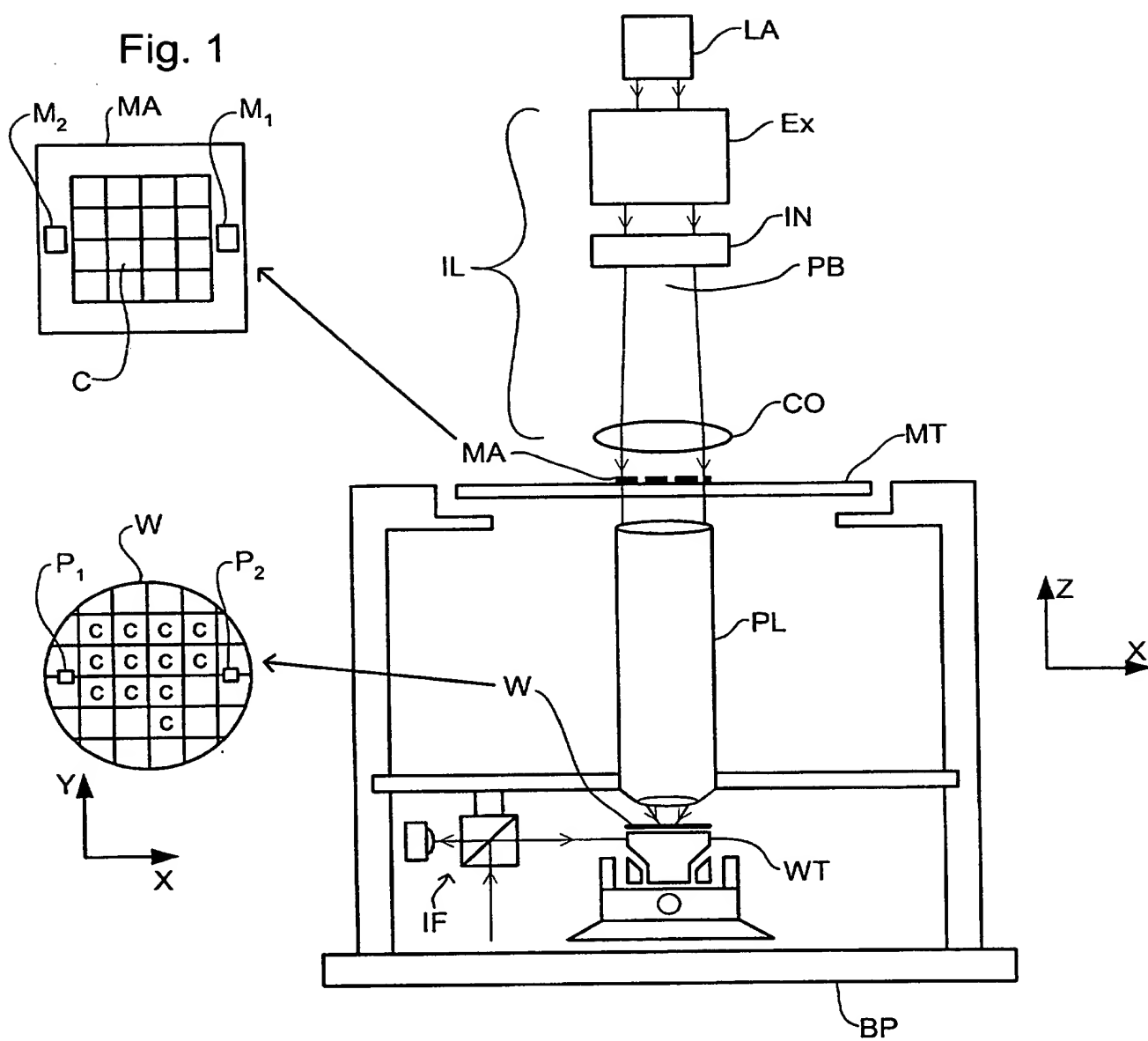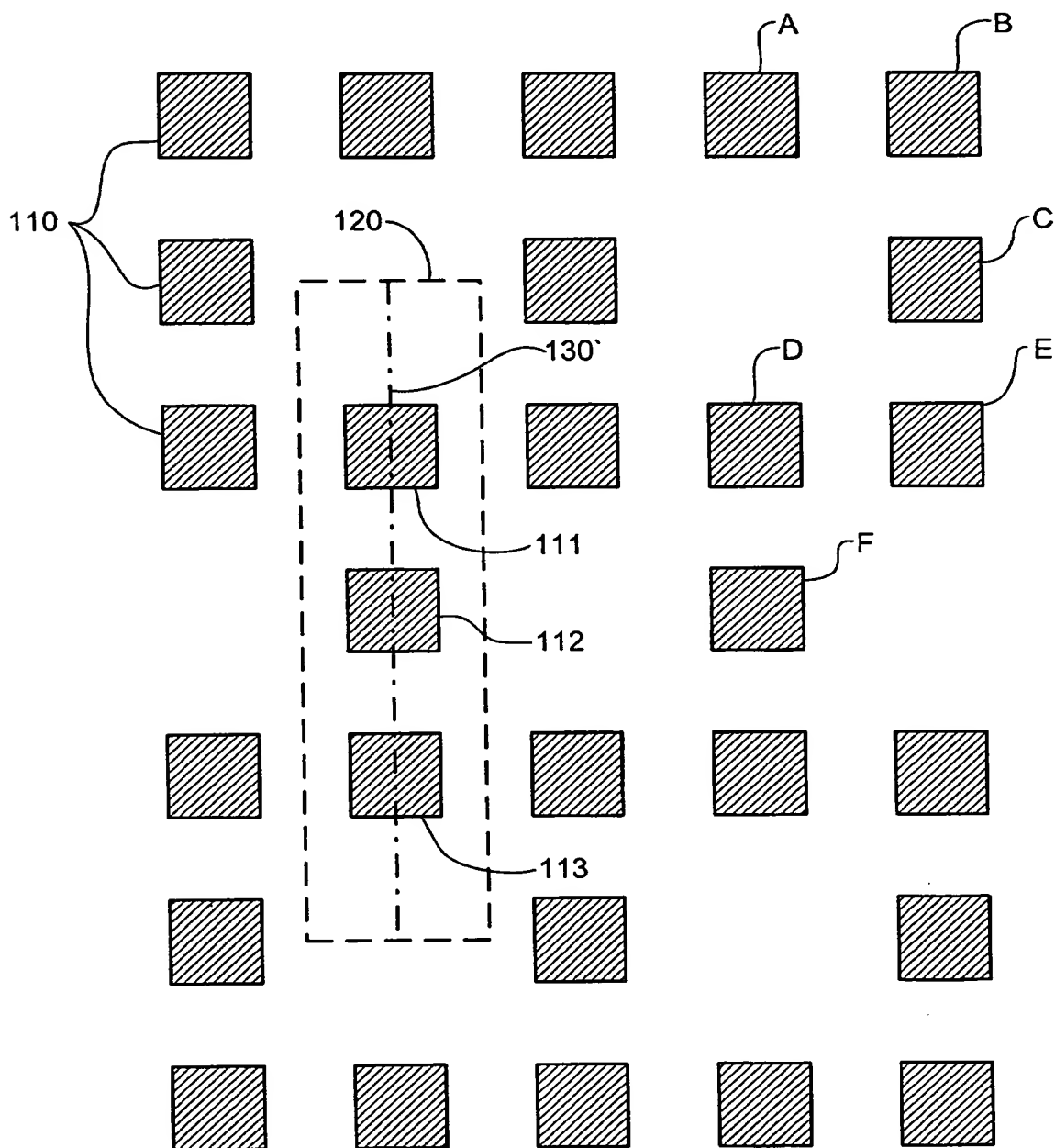
Fig. 4
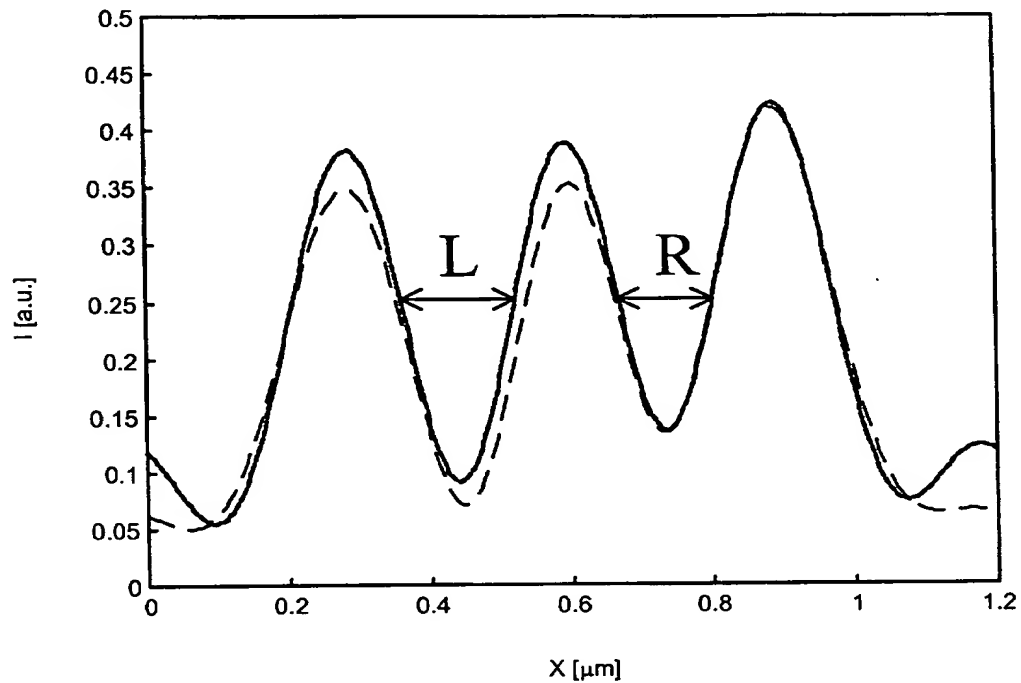
Fig. 11

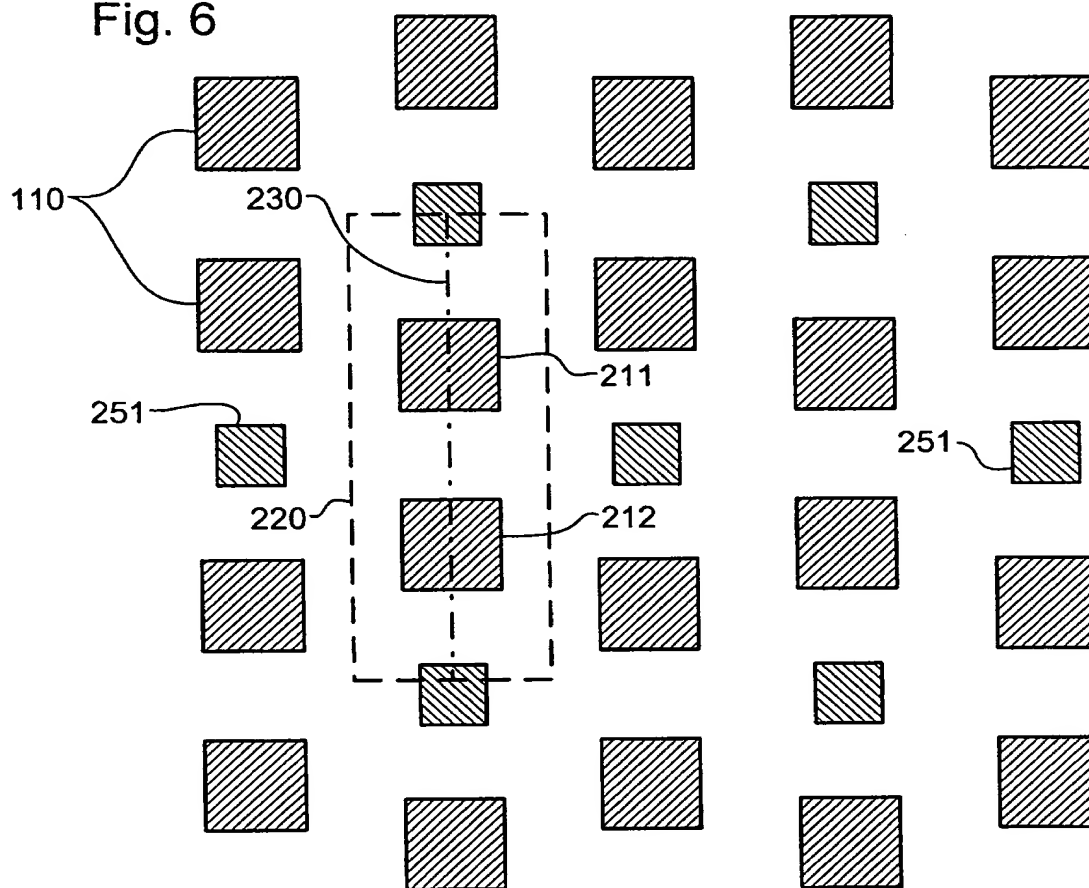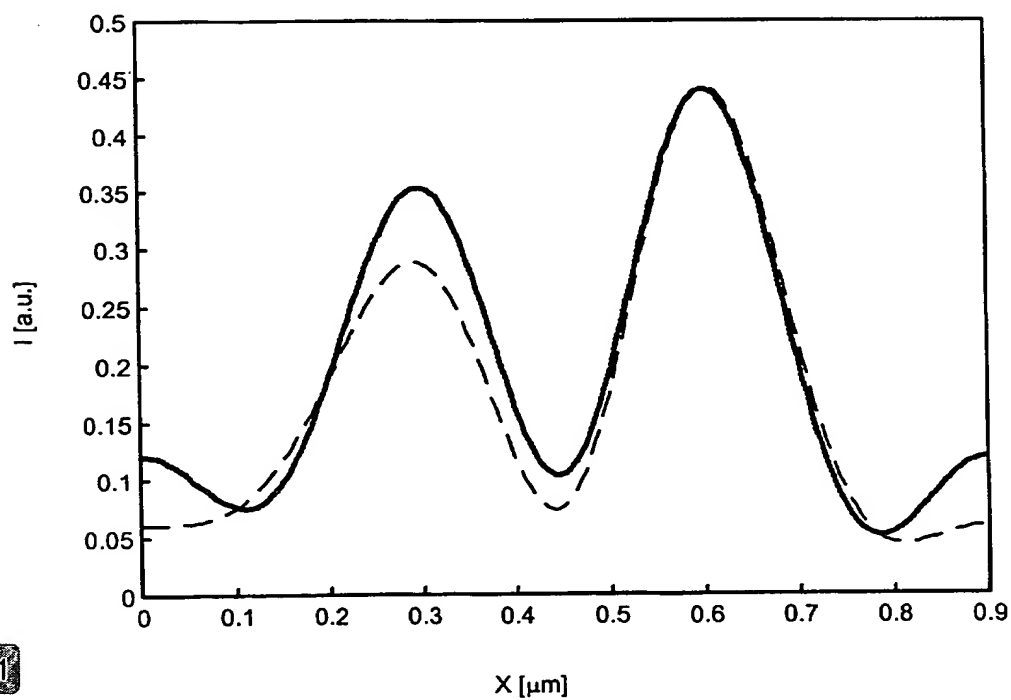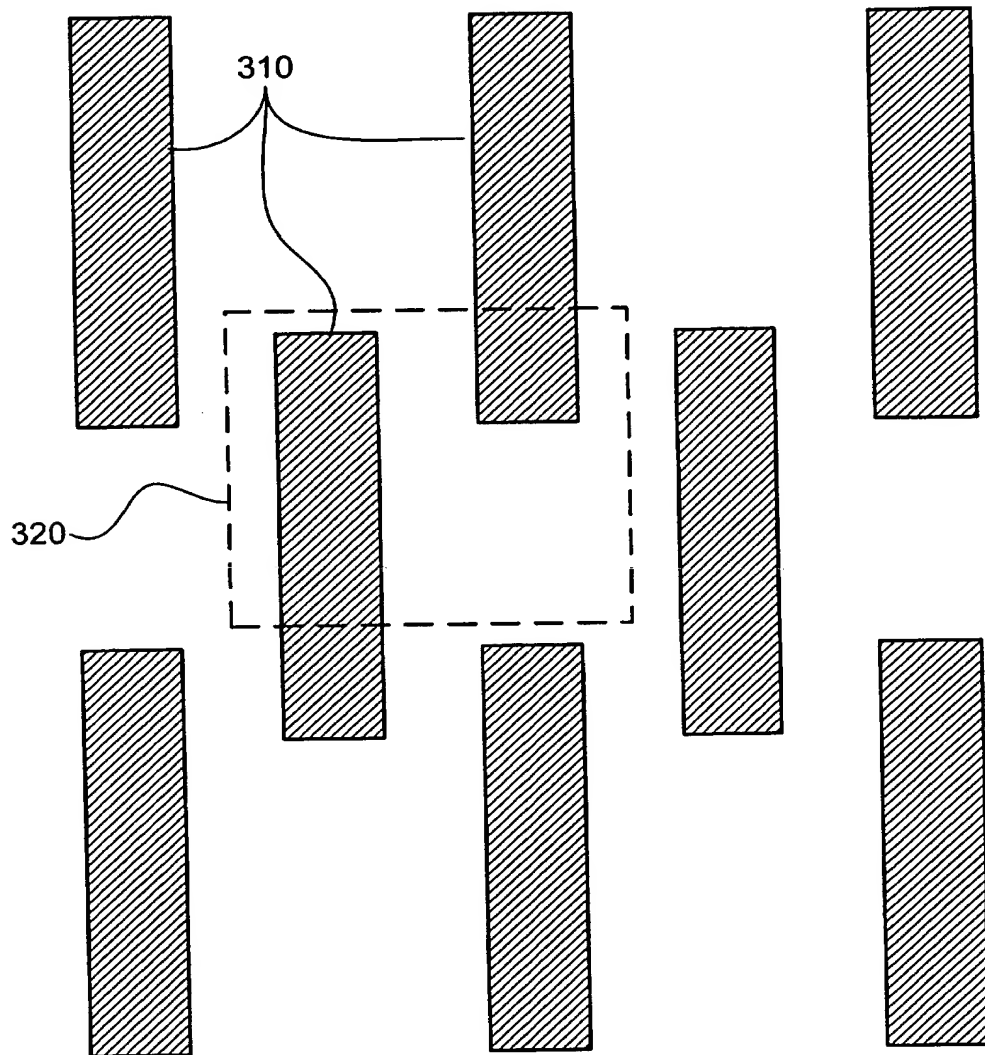| Table 1				
Aberration		Low order Zernikes		Higher orders
m	Name	Function	Term	Term
0	Spherical	$6r^4 - 6r^2 + 1$	Z9	Z16, Z25, Z36, Z37
1	X-Coma	$(3r^3 - 2r)\cos(\theta)$	Z7	Z14, Z23, Z34
1	Y-Coma	$(3r^3 - 2r)\sin(\theta)$	Z8	Z15, Z24, Z35
2	Astigmatism	$r^2 \cos(2\theta)$	Z5	Z12, Z21, Z32
2	45° Astigmatism	$r^2 \sin(2\theta)$	Z6	Z13, Z22, Z33
3	X-Three Point Aberration	$r^3 \cos(3\theta)$	Z10	Z19, Z30
3	Y-Three Point Aberration	$r^3 \sin(3\theta)$	Z11	Z20, Z31

Fig. 5

P-0198

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10